Human Planetary Landing Systems (HPLS) Capability Roadmap (CRM) Development

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HPLS Summary

The objective of this road mapping effort is to identify key capabilities that need to be developed to enable large human and human-support payloads to be safely delivered to the surface of planetary bodies.

- Earth, Mars and Moon landing systems are primary objectives.
- There is significant overlap with ESMD's on-going "Exploration Spiral 2" capabilities development efforts which focus on Lunar missions and Earth return - this team has chosen to place the initial emphasis on the needed key capabilities for human Mars landing.
- Comparison with needed capabilities for large scale Earth return and Lunar landing missions will be made later in the road mapping effort.

Relevance

Understanding the required capabilities necessary for safe human arrival on Mars is key to developing the long term strategic roadmap for most human exploration missions to the Moon and to Mars.

- We currently do not have a well-understood human-safe landing concept and methodology envisioned for Mars.
- The needed safe landing technologies for Mars have not been determined.
- Without the development of new or even “exotic” technologies, unacceptably low upper limits on the payload mass of a physically realizable human-safe landing system may exist.
- Lunar landings and lunar surface operations planning and experience are expected to contribute to the human Mars landing systems roadmap and vice versa, however significant work remains to define how the contributions will be made.

These are the beginning steps needed to define a viable vision of Human Mars Exploration.

HPLS CRM Core Team

Function	Name	Org	Specialty
Chair	Rob Manning	JPL	Systems
Co-Chair	Harrison Schmitt	Consult	Astronaut/Eng/Sci
Deputy Chr	Claude Graves	JSC	Entry
Member	Ray Silvestri	JSC	Shuttle Entry
Member	Ken Mease	UCI	Prec. Lndg.
Member	Bobby Braun	GaTech	Entry Systems
Member	Ethiraj Venkatapathy	ARC	Entry / TPS
Member	Dick Powell	LaRC	Entry Systems
Member	Juan Cruz	LaRC	Descent Systems
Member	Jim Masciarelli	Ball	Entry Guidance
Member	Wayne Lee	JPL	EDL Systems
Member	Bob Mitcheltree	JPL	EDL Systems Validation
Member	Tom Rivellini	JPL	Structures/Config.
Member	Mary Kae Lockwood	LaRC	Systems Analysis
Member	Rob Mueller	KSC	Mechanical Systems
Member	Aron Wolf	JPL	Prec. Lndg.
Member	Kent Joosten	JSC	Expl. Grp
Member	Marsha Ivins	JSC	Astronaut – Surface Habitat
Member	Barry Wilmore	JSC	Astronaut – Landing Systems

There are other "advocate" members who will contribute to this effort who are not listed here.

Input to the HPLS CRM Team

The Human Planetary Landing Capability Roadmap Team seeks information on current and potential future concepts, capabilities and technologies in the following areas as they relate to enabling future NASA missions in support of the Vision for Space Exploration:

- **Critical Activity Human Factors**
  - **Safety requirements, human-lander interaction and hazard avoidance, abort criteria, etc.**
- **Hypersonic Entry Vehicles Systems to accommodate very large cargo masses and volumes needed for human exploration**
  - **In-space assembly of hypersonic decelerators, deployable decelerator/ballutes, slender body decelerators, etc.**
- **Hypersonic guidance, navigation, and control systems algorithms, actuators, and sensors**
  - **Navigation systems, Mid-high L/D decelerators, Hypersonic aero-control surfaces, RCS CM off-set systems, etc .**
- **Supersonic decelerator systems**
  - **Hi mach parachutes, drag cones, etc.**
- **Subsonic decelerator systems**
  - **Large parachutes, cluster parachutes, etc.**
- **Parachute / other subsonic aero-guidance systems and sensors**
- **Terminal Descent Control & Guidance Systems and inertial and other navigation sensors**
  - **Propulsion, terminal guidance, Thrust vector control configurations & requirements, velocimetry, altimetry, pin-point landing sensors, etc.**
- **Terminal Descent hazard detection sensors**
  - **Lidar, IR, RADAR, etc.**
- **Touchdown systems and sensors**
  - **Landing system arresters and righting systems, TVC cut-off aids.**

Topics of special interest include:

- **System architectures & system configurations for Aerocapture/Entry, Descent and Landing**
- **Hypersonic, subsonic and touchdown test capabilities & facilities**
- **Pinpoint landing systems**
- **Unique requirements for Human Safety and Planetary Protection**

This list is not intended to be comprehensive.

CRM Process/Approach

Develop capability breakdown structure (CBS)

Review previous and current roadmap & DRMs

- DRMs (examples):
  - Human Exp of Mars: Ref mission of the NASA Exp Study Team Mar 1997 Hoffman& Kaplan JSC NASA Pub 6107
  - Ref Miss. Ver 3 Addendum by Bret Drake JSC, '98 NASA SP 6107-ADD
  - The Mars Surface Ref Mission: A Description of Human & Robotic Surface Activities. Hoffman NASA/TP-2001-209371
- Revise CBS structure if necessary.

Recruit NASA, academia and industry experts as "advocates" for DRMs,concept, capability and technology developments.

- This workshop is the first step.

Invitation-only HPLS CRM Workshops

- Three, 2-day workshops are planned in Dec - Mar. 2004
- Draft report due in March

Roadmaps will be reviewed by a board from the National Academy of Engineering.

The integrated roadmaps will be published in late 2005.

Status of HPLS CRM effort

The HPLS CRM effort has just begun.

- Only 3 telecons to date.

The core HPLS CRM team has been selected.

- This team represents a wide range of applicable disciplines and relevant experiences.

The workshop dates have been selected for the first 2 workshops.

Invitees beyond the core team have not been finalized.

- Depending on required skill level, we will consider additional invitees.

The final form and emphasis of the HPLS CRM has not been agreed to by the team.

- The workshops are intended to first identify the state of understanding and state of the art in large landing systems.
- We expect that key missing capabilities will fall out of workshop #1 (December), but that specific identification and recommendation for advancement of key capabilities will not occur until work until January.

Concerns

There is an absence of a clear requirements and baseline design for landing large (20 - 50 MT) payloads on Mars.

Significant work remains to define and execute the system-level trades that will point to the needed capabilities.

- Some concepts, capabilities and technologies may be and should be pursued prior to completion of these trades.
- The results of the trade studies are likely to depend on the capabilities assumed for each of the EDL (entry, descent and landing) technologies (e.g. assumed heat rate/heat load limits for inflatables).
- Iteration should be expected.

It is unlikely that this roadmap will be able to determine specifically which technology is required, however a plan to develop a strategy with identification of key milestones should result by March.

Today's HPLS White Papers

"ATK Elkton Innovative Landing"

- Charley Bown, ATK Thiokol,

"Rotor Landing Technology for CEV Earth-to-Orbit Crew Transport'

- Jeff Hagen, self

"Current and potential capabilities and technologies related to integrated thermal, radiation and micrometeoroid protection systems (Aeroentry/Aerobraking, Lightweight PMC)"

- Larry Hines, Jan Thornton: Lockheed Martin

"The Australian Hypersonics Initiative"

- Allan Paull, The University of Queensland

"Reuse of International Space Station (ISS) Modules as Lunar Habitat"

- Jamie Miernik, ERC, Inc